

WHAT IS CLAIMED IS:

1. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal;

a step size decision unit for receiving the error signal and a step size upper limit value and a step size lower limit value being an upper limit value and a lower limit value of a step size as a step for the update of the tap coefficient, adaptively generating a step size which corresponds to the error signal in a range of the step size upper limit value or smaller and the step size lower limit value or larger, and outputting the generated step size; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update.

2. The waveform equalization controller of Claim 1 wherein the step size decision unit comprises:

a multiplier for squaring the error signal to generate

a square error;

a square error storage unit for containing the square error which has been generated at a previous tap coefficient update;

a subtracter for generating a difference between square errors, which is a difference between the square error output by the multiplier and the square error stored in the square error storage unit generated at the previous tap coefficient update;

a first comparator for comparing the square error with a first threshold;

a second comparator for comparing the square error with a second threshold;

a third comparator for comparing an absolute value of the difference between square errors with a third threshold;

a step size storage unit for containing a step size which has been used at the previous tap coefficient update; and

a step size increasing/decreasing unit for receiving the step size which has been stored in the step size storage unit, an output of the first comparator, an output of the second comparator, an output of the third comparator, the step size upper limit value and the step size lower limit value, and generating a step size which is to be used for this tap coefficient update.

09698020-403000

3. The waveform equalization controller of Claim 2 wherein the second threshold is such a value that when the square error is larger than the value an operation of the waveform equalizer is trending toward divergence;

the first threshold is such a value that when the square error is smaller than the value the operation of the waveform equalizer is either converging or has converged;

the third threshold is such a value that in the case where the square error is smaller than the first threshold, when an absolute value of the difference between square errors is larger than the third threshold the operation of the waveform equalizer is converging and when the absolute value is equal to or smaller than the third threshold the operation of the waveform equalizer has converged; and

the step size increasing/decreasing unit decreases the step size by a predetermined amount when it is judged from comparison results of the first to third comparators that the square error is larger than the second threshold,

decreases the step size by a predetermined amount when the square error is smaller than the first threshold and the absolute value of the difference between square errors is equal to or smaller than the third threshold,

increases the step size by a predetermined amount when the square error is smaller than the first threshold and

09593020 103000

does not change the step size in other cases.

. decreases the step size at a predetermined rate when the square error is smaller than the first threshold and the absolute value of the difference between square errors

is equal to or smaller than the third threshold,

increases the step size at a predetermined rate when the square error is smaller than the first threshold and the absolute value of the difference between square errors is larger than the third threshold, and

does not change the step size in other cases.

5. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal;

a signal judgement unit for judging whether a probability of a judgement error in the error estimation for the output signal is larger or smaller, and outputting a judgement signal;

a step size decision unit for receiving the judgement signal and outputting a value according to the judgement signal as a step size which is a step for the update of the tap coefficient; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis

09598020 103000

of the error signal, the step size, and a data to be used for the tap coefficient update.

6. The waveform equalization controller of Claim 5 wherein the signal judgement unit outputs three kinds of the judgement signal of:

the judgement signal indicating that the output signal is known;

the judgement signal indicating that the probability of the judgement error for the output signal is smaller; and

the judgement signal indicating that the probability of the judgement error for the output signal is larger.

7. The waveform equalization controller of Claim 6 wherein the step size decision unit outputs a first step size set value as the step size when the judgement signal indicates that the output signal is known,

outputs a second step size set value which is smaller than the first step size set value when the judgement signal indicates that the probability of the judgement error for the output signal is smaller, and

outputs a third step size set value which is smaller than the second step size set value when the judgement signal indicates that the probability of the judgement error for

000001 02036960

0963030-303030

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update.

a comparator for comparing an absolute value of the

error signal with the threshold; and

a selector for selecting one of the first step size set value and the second step size set value on the basis of a comparison result output by the comparator, and outputting the selected step size as the step size.

10. The waveform equalization controller of Claim 9 wherein

the threshold value is such a value that when the absolute value of the error signal is equal to or smaller than the threshold the waveform equalizer has nearly converged; and

the step size decision unit outputs the first step size set value as the step size when the absolute value of the error signal is equal to or smaller than the threshold, and outputs the second step size set value as the step size when the absolute value of the error signal exceeds the threshold.

11. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an

000001 02085960

an error quantization unit for converting the error signal into a quantized error signal having a value of powers of 2, and outputting the quantized error signal; and

12 The waveform equalization controller of Claim 11
wherein

13. The waveform equalization controller of Claim 11
wherein

the error quantization unit converts the error signal into the quantized error signal having the same sign as the error signal and a minimum absolute value among the powers

the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having

the same sign as the data to be used for the tap coefficient update and a maximum absolute value among the powers of 2, which is equal to or smaller than an absolute value of the data to be used for the tap coefficient update, and outputting the quantized data.

16. The waveform equalization controller of Claim 14 wherein

the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having the same sign as the data to be used for the tap coefficient update and a minimum absolute value among the powers of 2, which is equal to or larger than an absolute value of the data to be used for the tap coefficient update, and outputting the quantized data.

17. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal;

a step size quantization unit for converting a step size

09693020 103000

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the quantized step size and a data to be used for the tap coefficient update.

the step size quantization unit converts the step size into the quantized step size having a maximum value among the powers of 2, which is equal to or smaller than the step size, and outputs the quantized step size.

the step size quantization unit converts the step size into the quantized step size having a minimum value among the powers of 2, which is equal to or larger than the step size, and outputting the quantized step size.

20. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm,

and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the output signal;

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update; and

a coefficient update timing control unit for receiving the error signal and outputting a update timing signal which controls a timing when the coefficient updating amount calculation unit calculates the tap coefficient updating amount at intervals of plural symbols.

21. The waveform equalization controller of Claim 20 wherein

the coefficient update timing control unit controls the timing of the coefficient updating amount calculation unit calculating the tap coefficient updating amount to be at a first symbol after an interval of predetermined symbols

09698020 103000

or more from a previous timing and when the error signal is not 0.

22. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprising:

an error estimation unit comprising an output error estimation unit for receiving an output signal of the waveform equalizer and outputting an output error signal, and a coefficient updating error generation unit for receiving the output error signal and the output signal and outputting an error signal which is obtained by reducing a partial section of the output error signal at a predetermined rate; and

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a date to be used for the tap coefficient update.

23. A waveform equalization controller which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm

09698020-103000

a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update.

the coefficient updating error generation unit outputs the same value as the output error signal, as the error signal, when it is detected from the error rate signal that the rate of the error included in the output signal is smaller than a predetermined rate.

an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal;

a step size decision step of adaptively deciding a step size in a range of a step size upper limit value as an upper limit value of a step size which is a step for the update of the tap coefficient or smaller, and a step size lower limit value as a lower limit value of the step size or larger, on the basis of the error signal; and

a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update.

the step size decision step comprises:

a multiplication step of squaring the error signal to generate a square error;

a step size generation step of generating a step size which is to be used for this tap coefficient update on the basis of the step size which has been used at the previous tap coefficient update, a comparison result in the first comparison step, a comparison result in the second comparison step, a comparison result in the third comparison step, the step size upper limit value and the step size lower limit value.

a step of estimating an error of an output signal of

a step of judging whether a probability of a judgement error in the error estimation for the output signal is larger or smaller, and generating a judgement signal;

a step of calculating a tap coefficient updating amount on the basis of the error signal, the step size, and a data to be used for the tap coefficient update.

28. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprising:

an error estimation step of estimating an error of the output signal of the waveform equalizer from the output signal, and generating an error signal;

a step size decision step of deciding a step size as a step for the update of the tap coefficient on the basis of the error signal, a threshold and plural step size set values; and

a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis

an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the

a coefficient update timing control step of generating an update timing signal which controls a timing of calculating the tap coefficient updating amount at intervals of plural symbols on the basis of the error signal; and

31. The waveform equalization control method of Claim 30
wherein

32. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of

a step of estimating an output error from an output signal of the waveform equalizer and generating an output error signal;

a step of generating an error signal which is obtained by reducing a partial section of the output error signal at a predetermined rate on the basis of the output error signal and the output signal; and

a step of calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a date to be used for the tap coefficient update.

33. A waveform equalization control method for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprising:

an output error estimation step of estimating an output error from an output signal of the waveform equalizer, and generating an output error signal;

an error rate signal generation step of generating an error rate signal which indicates a rate of an error included in the output signal of the waveform equalizer;

a coefficient updating error generation step of
generating an error signal to be used for the update of the

a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update.

when it is detected from the error rate signal in the coefficient updating error generation step that the rate of the error included in the output signal is smaller than a predetermined rate, the same value as the output error signal is generated as the error signal.